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Commercial Greenhouse Bell Pepper Production *in Alberta*

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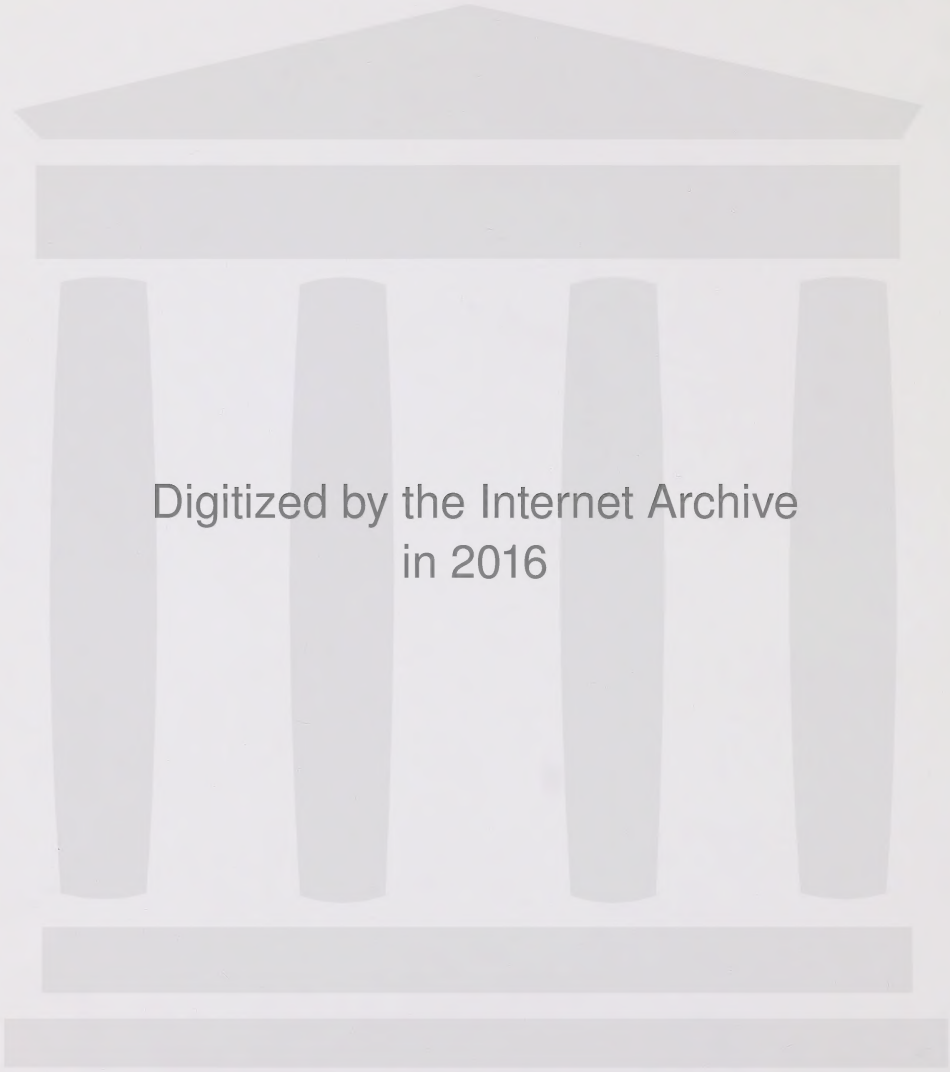
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Bell Pepper Production
in Alberta

James Calpas, P. Ag.

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NOTE:
The depiction of certain brands or products in the images in this publication does not constitute an endorsement of any brand or manufacturer. The images were chosen to illustrate certain aspects of commercial greenhouse production only, and the author does not wish to suggest that the brands or products shown are in any way superior to others. Growers should note that there are many products on the market, and buyers should research these products carefully before purchasing them.

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Sweet Bell Peppers

Introduction

Bell peppers (*Capsicum annum L.*) originate from central and south America where numerous species were used centuries before Columbus landed on the continent. The cultivation of peppers spread throughout Europe and Asia after the 1500's.

Although bell peppers are perennials, they grow as annuals in temperate climates. They are sensitive to low temperatures and are relatively slow to establish.

As there is little field production of bell peppers in Alberta, greenhouse production provides most of the local source of this product (Figure 1). Greenhouse pepper production is based on indeterminate cultivars, where the plants continually develop and grow from new meristems that produce new stems, leaves, flowers and fruit.

Figure 1. *Canopy of a healthy greenhouse sweet bell pepper crop.*

By comparison, field pepper cultivars are determinate; that is, the plant grows to a certain size, produces fruit and stops growing and then eventually dies. Indeterminate cultivars require constant attention to direct and manage their growth, to establish and maintain a plant balance and to optimize yield.

Greenhouse pepper production is based on a year-long production cycle. Typically, seeding occurs in early to mid-November. Plants are moved from the nursery into the production greenhouses six weeks later, just before Christmas. Harvest begins in late March and continues through to the following November. It takes roughly four months from seeding the crop to the first pick (Figure 2).

Figure 2. *Basket of red sweet bell peppers ready for market.*

Production of Sweet Bell Peppers

Greenhouse sweet bell peppers are a high impact, superior product primarily grown in three colors: red, yellow and orange. The majority of commercial production area is based on red (85 per cent), followed by yellow (10 per cent) and orange (5 per cent); however, these percentages are subject to change to meet shifts in consumer demand (Figure 3).

Figure 3. *Ripening red sweet bell pepper.*

No matter what the final color of the pepper, all sweet peppers start out green, and the final color develops as the fruit ripens. The color of the mature pepper is determined by the cultivar grown (Figure 4). Harvesting the full-size peppers when they are still green is not profitable because the mature colored peppers command a better price.

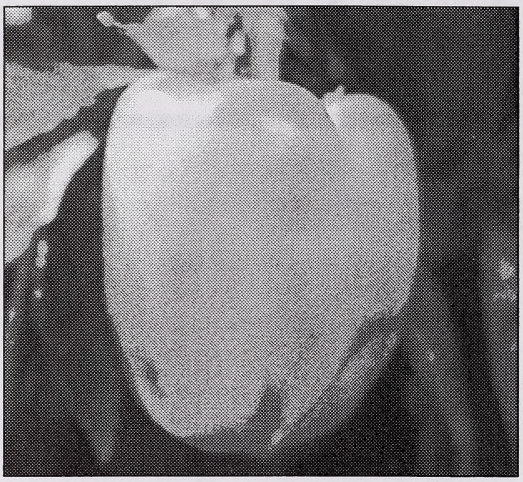


Figure 4. *Yellow sweet bell pepper.*

Greenhouse pepper production is based on a full-year cycle (Figure 5). The transplants go into the production greenhouse in approximately mid to late December at six weeks of age. The first pick of fruit begins in about late March/early April and continues to the following December. The greenhouses are empty for only two or three weeks during the year to allow for the removal of the old crop, the thorough cleaning of the greenhouse and the setting up of the greenhouse for the new crop.

One crop a year is grown; that is, production for the entire year is based on the same set of plants. Since it takes approximately 20 weeks (4 months) from seeding the crop to first pick, growing more than one crop a year is not profitable.

Since lower winter light levels do not support profitable crop production, growers do not carry a fully producing crop over the month of December. This is also why December is usually the month when crops are pulled and the new crop goes in. Supplementary lights are generally not cost effective for trying to carry a producing crop over the winter months, through December, January and February.

The reality is that the prices received for the crop in the winter months are always higher than in summer, when the greenhouse produce competes with the field produce. Winter production would offer a

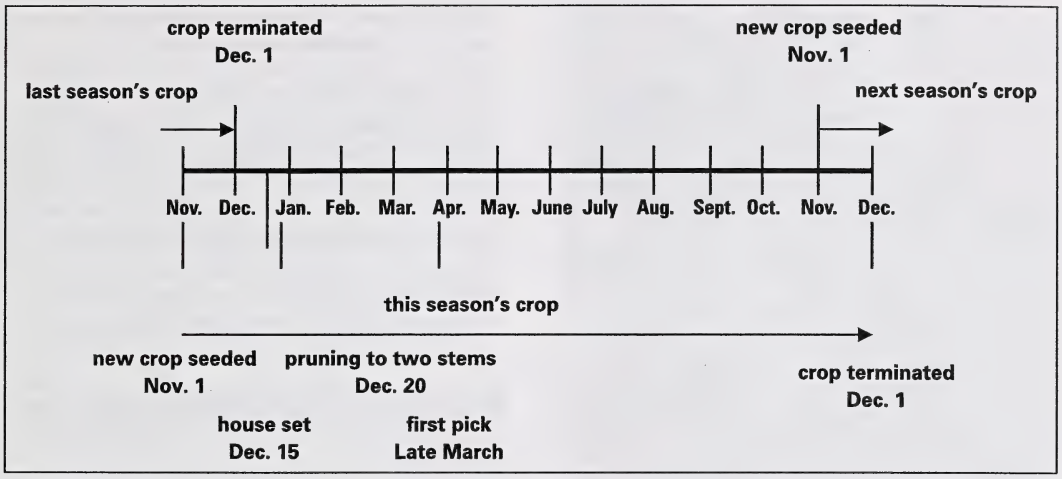


Figure 5. Typical sweet bell pepper production cycle.

considerable price advantage for produce if the yield and quality of the fruit were maintained. As crop production techniques improve, running a producing crop over the winter months may prove profitable. Staggered crop schedules and inter-cropping (planting young seedlings among an already producing crop) may allow for full-year production. However, this publication will discuss pepper crop production following the single crop cycle, outlined in Figure 5. An approximate target yield for introductory growers would be 23 kg/m^2.

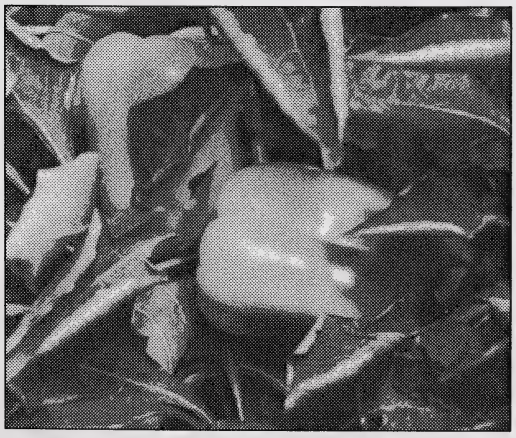


Figure 6. Orange sweet bell pepper.

Sweet bell peppers are grown as a tall crop, and provisions for working a tall crop must be incorporated into the greenhouse to grow the crop successfully. The main structural consideration for greenhouse sweet pepper production is the height of the greenhouse, the gutter height.

A minimum recommended gutter height for sweet peppers would be 3.9 meters (13 feet), and the trend in greenhouses is to build them taller, with some greenhouses coming in at 5 meters (17 feet) at the gutters. The overhead support wires that support the weight of the plants, are generally 0.3 meters (1 foot) below the gutter, and this feature serves as an approximate limit to the crop height.

Having high gutters essentially allows for a level of "forgiveness" in pepper production. If the plants become unbalanced during the production cycle and put more resources into vegetative production, they can grow taller in a short time. With higher gutters, growers are able to bring the plants back into balance without necessarily having to worry that the crop will reach the roof too early in the crop cycle, resulting in the early termination of the crop.

Figure 7. *Young sweet bell peppers developing towards full size before turning their mature color.*

Other considerations for working the pepper crop as it grows taller include provisions for being able to work with the plants, for pruning and for harvesting. One method for working on the crop is the pipe and rail system. This system allows for electric carts to move on pipe rails running the length of each of the rows of the crop. These carts have adjustable platforms that can be raised to allow employees to continue to work the crop as it grows taller. It is important that the carts be designed for maximum stability when tall crops are worked, and as gutter heights increase in new greenhouses, the width of the rails also have to increase to ensure the safety of those working on the carts.

Selecting Cultivars

Selection of greenhouse sweet pepper cultivars depends on color, disease resistance, performance and yield. A variety of seed companies and distributors offer greenhouse sweet pepper cultivars, and the "latest" cultivars are always subject to change when superior cultivars are developed.

Before selecting cultivars, investigate what is currently being grown by the industry in your area because the suitability of cultivars can vary depending on region. Growing more than one color of pepper in the same greenhouse is not recommended unless the colors are grown in separate environments. The cultural requirements of the different cultivars can be distinct enough to require that the environments be managed differently to obtain the maximum yield.

Pepper Plant Propagation

Seeding

The seedling nursery or propagation area should be cleaned and disinfected with a 10 per cent bleach solution or other disinfecting compound. Ensure that fresh seed is used because seed greater than one-year-old can have reduced germination and vigour.

Seeding usually takes place around November 15, although the date can vary depending on the grower. Seed into rockwool plugs that have been wetted with a feed solution with an E.C. of 0.5 mmho at 25 to 26°C. Use a standard pepper feed solution at approximately pH 5.8 that has been diluted from an E.C. of 2.5 to 0.5 mmho. The concepts of E.C. (electrical conductivity), mmho, W/m^2 (watts per square meter) and VPD (vapour pressure difference or deficit) are explained in the first publication in this series, *Commercial Greenhouse Production in Alberta*.

Be sure the temperature of the seeded rockwool plugs is maintained at 25 to 26°C during germination, and maintain the relative humidity in the nursery at 75 to 80 per cent (VPD of 3 to 5 gm/cm^3). Maintain air temperatures at 25 to 26°C day and night. Do not allow the plugs to dry out; keep them moist using the warm (25 to 26°C) 0.5 mmho pepper feed solution. The pepper seedlings should begin to emerge in about 7 to 10 days. Use supplemental light to ensure approximately 140 to 160 W/m^2, 18 hours a day.

Once the seedlings have emerged, the temperature of the rockwool plugs should be reduced to 23 to 24°C.

The seedlings can be misted lightly once a day for the first four days after emergence. Four days after the seedlings have emerged, allow the relative humidity to drop to 65 to 70 per cent. Do not allow the rockwool plugs to dry. Apply light applications of the 0.5 mmho feed solution; the plugs should be moist but not sopping wet.

First transplanting: rockwool blocks

When the first true leaves are visible approximately two weeks after seeding, the seedlings are transplanted into the larger rockwool cubes. The rockwool blocks are well wetted with full strength feed solution, E.C. 2.5 mmho at approximately 23°C, before transplanting. The seedling rockwool plug is rotated 90 degrees as the seedling is placed into the rockwool cube (Figure 8). This placement allows for more root development along the length of the young stem.

The root zone temperatures should be allowed to drop to 21°C just after transplanting. The blocks should be watered from the bottom (E.C. of 2.5 mmho, 21°C) every second day, again ensuring that the blocks remain moist, but not sopping wet. Target root zone temperatures of 21°C for the next two weeks, when the root zone temperature is dropped to 20°C. Maintain air temperatures at 24°C. during the day and 22°C at night, for a 24-hour average temperature of 22°C.

Once the seedlings have established in the rockwool cubes, monitor the E.C. of the cube twice a week. The E.C. will rise and can reach levels of up to 7.0 mmho

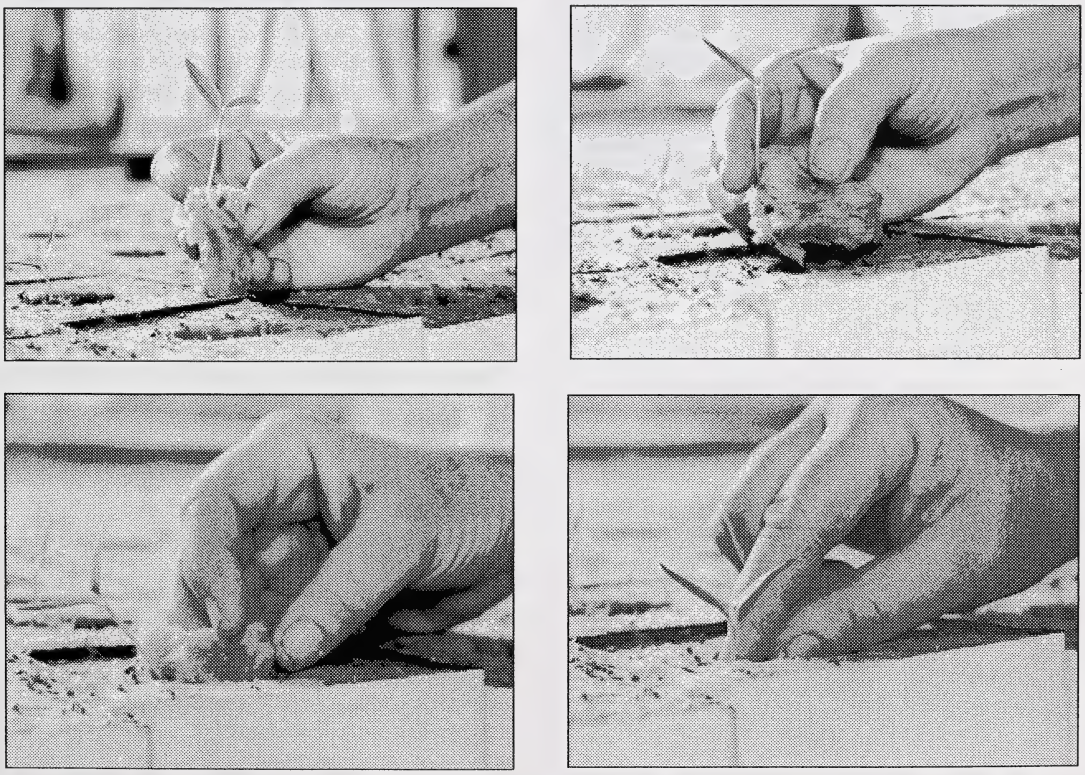


Figure 8. *Transplanting the young seedlings into the rockwool blocks; the plug is rotated 90° as it is placed into the space in the top of the block to allow for more root development.*

without damaging the seedlings. At three weeks after seeding and one week after transplanting, the E.C. of the feed solution should be reduced from 2.5 mmho to 2.0 mmho. This reduction is made to target a root zone E.C. of 3.0 to 3.5 mmho in the block when the plants are ready for the second transplanting directly into the production greenhouse.

As the plants establish and develop in the rockwool blocks, care must be taken to ensure they have adequate space. Crowded plants will stretch and become tall and spindly, resulting in poorer quality transplants. The plants should be spaced whenever their leaves begin to touch (Figure 9). Maintain supplementary lighting, 18 hour days at 160 W/m^2.

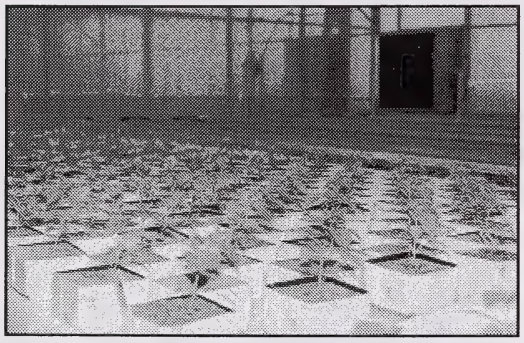


Figure 9. *Plants are spaced as soon as their leaves begin to touch, which prevents the plants from stretching.*

At five weeks after seeding the plants, the target root zone temperature should be 20°C (Figure 10). The supplemental lighting is reduced from 18 hours to 14 hours daily to help reduce the "light shock" once the young plants are transplanted into the production greenhouse where no supplemental lighting is used. The air temperatures should be 20°C day and night (24-hour average of 20°C). The root zone E.C. should now be in the range of 3.0 to 3.5 mmho. Never water with clear water to reduce root zone E.C.

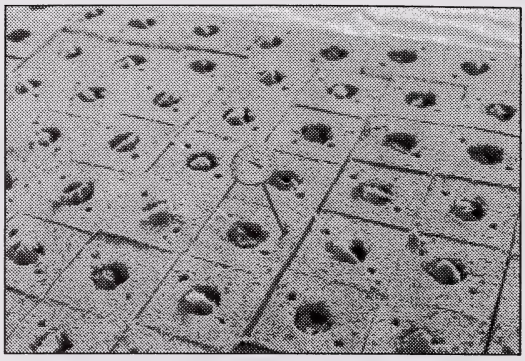


Figure 10. *Monitoring to ensure the proper root zone temperatures are maintained.*

Production greenhouse growing media

A number of options for the type of growing media can be used in the production greenhouse, and these are outlined in the *Commercial Greenhouse Production in Alberta* publication. For commercial pepper production, this publication will focus on sawdust as the growing media.

Planting density

Before the young plants are transplanted, the production greenhouse is set up to receive the plants. A planting density of 3 plants/m^2 is recommended. The sawdust bags are set down in double or single rows according to the requirements for meeting the planting density target.

To determine the number of plants required for the greenhouse, multiply the production area (in meters) by three. The standard pepper sawdust bag will hold three plants and has a volume of approximately 20 litres with dimensions of 23 x 86 x 10 cm (10 x 34 x 6 inches) when full.

The number of rows required is then calculated. For double rows, the walkway, the distance between bags from adjacent double rows, is approximately 76 centimeters (30 inches). The distance between bags in the two adjacent single rows of the double row is approximately 20 centimeters (8 inches), with a total width of 70 centimeters (28 inches) for the full double row.

This information allows for the determination of the number of double rows that can be placed in the greenhouse. In actual fact, determining the number and location of the rows occurs very early in the greenhouse construction phase, as the drainage ditches as well as the pipe and rail heating system are "fixed" and put in place well in advance of the crop.

Knowing the number of bags required and dividing this number by the number of rows (double rows preferred), you will arrive at the number of bags required per row required to reach the target plant density. The number of bags in a row are spaced out evenly along the length of the row.

House-set: transplanting into the production greenhouse

Young pepper plants are ready to be transplanted into the production greenhouse at six weeks of age. The plants should be approximately 25 cm (10 inches) tall, have about four leaves on the main stem and have begun to branch. The main stem usually branches into two to three branches; the point of branching is sometimes referred to as the "fork." Examination of the underside of the rockwool blocks should reveal a number of roots beginning to develop through the bottom of the block. This growth is another indication the plants are ready to be transplanted into the greenhouse to allow the roots to "knit" into the growing media, e.g. sawdust bags or rockwool slabs.

The growing media should be wetted, or "conditioned," with nutrient feed solution (E.C. 2.5 to 3.0 mmho) for 24 hours before the plants are set onto the media (Figure 11). The general rule is to condition the media with feed solution at the same E.C. as exists in the rockwool block. It is also important to ensure that the media is at 20°C and that this root zone temperature is maintained throughout the remainder of the growing season.

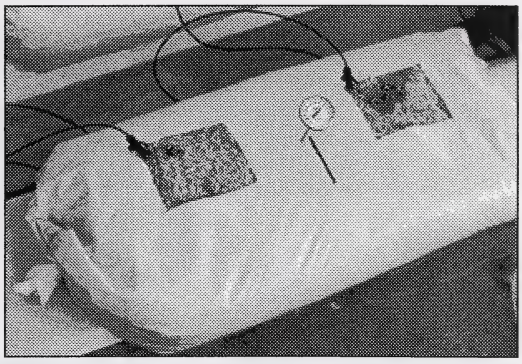


Figure 11. *Conditioning the sawdust bags 24 hours before house-set.*

The plants are then set onto the media, ensuring good contact between the bottom of the rockwool block and the growing media (Figure 12). If sawdust bags are used as the growing media, two to three plants are grown per 20 litre sawdust bag, and the bags are slit to provide drainage. The slits are approximately 4 cm (1.5 inches) long and are made on the sides of the bags facing the drainage channel, with one slit placed between every two plants. The slits allow the bags to drain completely, which helps avoid "pooling" of the feed solution at the bottom of the bag.

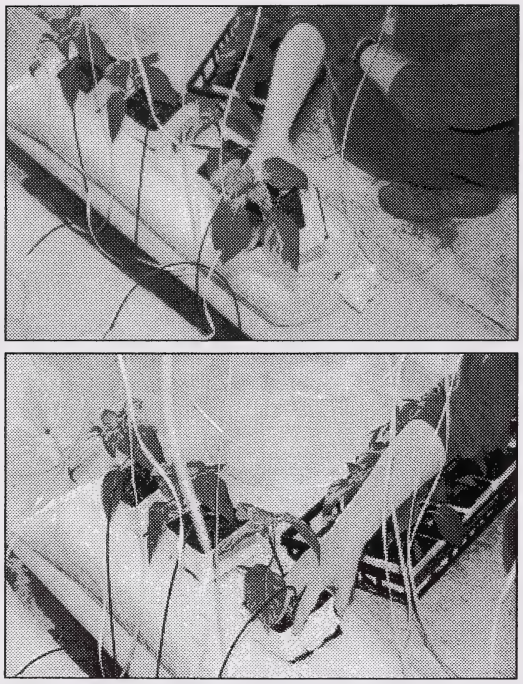


Figure 12. *"House-set": transplanting into the production greenhouse.*

For the first week in the greenhouse, the day/night temperatures are maintained at a constant 20 to 21°C, with a target relative humidity of 70 to 80 per cent (VPD of 3 to 5 gm/cm^3). Maintain CO_2 levels at 800 to 1,000 ppm.

The primary goals at this stage of the production cycle are to establish the young pepper plants on the media and ensure they develop a strong root system. Generally speaking, if the plants do not establish strong roots early, when they are quite young, they will not develop a strong root system later in the season, once the focus of the plants shifts towards fruit production (Figure 13).

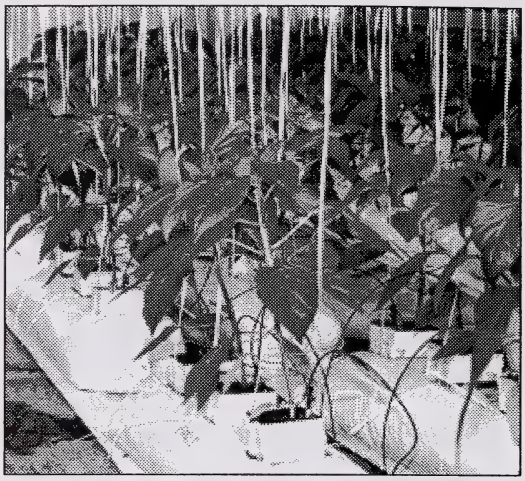


Figure 13. *Young plants rooted well into the bag, two weeks after transplanting.*

Careful attention should be paid to the application of the feed solution; target a 5 to 10 per cent overdrain. Overwatering at this point will hinder the development of a strong root system, resulting in a root system that will not perform well under the intense light conditions in the coming summer months. Increase the amount of nutrient solution delivered to maintain the 5 to 10 per cent overdrain target as the plants grow larger. Maintain a feed E.C. of 2.5 to 3.5 mmho. The root zone E.C. can be allowed to rise to about 4.0 to 4.5 mmho. As the season progresses and light levels begin to improve, the root zone E.C. should be brought down to 3.5 to 4.0 mmho.

One week after house-set, target day temperatures of 21°C and night temperatures of 16 to 17°C for a 24-hour average of 20 to 21°C. The optimum temperature for vegetative growth in peppers is between 21 and 23°C and for yield, 21°C. Establishing the difference in day/night temperature, while maintaining the target 24-hour average temperature, directs the plants to set flowers and maintain enough vegetative growth required for optimum fruit development and yield.

Pruning and plant training

Greenhouse pepper plants are indeterminate plants; that is, they continually grow new stems and leaves. For this reason, the plants have to be pruned and trained on a regular basis to ensure a balanced growth for maximum fruit production.

Pepper plants are managed with two main stems per plant, resulting in a density of six stems/m^2 from an initial planting density of three plants/m^2. Pruning also improves air circulation around the plant, which helps reduce disease. Plants are generally pruned every two weeks. As new leaves and lateral side shoots develop from the axils of the new nodes on the growing stems, they have to be pruned to maintain the two main-stem architecture of the plant.

The pepper flowers also develop at the nodes. A node is defined as a point on the stem from which leaves arise, and the length of stem between nodes is called an internode. The term "axil" refers to the upper angle formed by the junction of a leaf (or lateral) with the stem.

After about one week in the greenhouse, all the plants will have developed two to three stem shoots at the fork. At this point, the plants should be pruned to leave the two strongest stems. These two stems will be managed to carry the full production of the plants throughout the year.

Each stem will grow to a height of up to 4 meters (13 feet) and will require support to remain upright. Poly-twine hung from the overhead support wires is used to support each stem. The twine is tied to the main stem about 30 centimeters (12 inches) up from the block, one length of twine per stem. Ensure that the twine is not tied too tightly to the stem, or the stem can be damaged as it expands.

One other approach with the twine is to lay the twine on the sawdust bag just before transplanting the plant onto the sawdust. As the plant roots into the sawdust, it secures the twine. Enough slack is left in the twine so that it can be twisted around the growing and developing stem.

Early in the season, the plants are pruned to one leaf per node; that is, the main leaf at the node is allowed to develop, and the lateral stem developing from the node is removed. Beginning in April, a second leaf can be left to develop at every node on the main stem. The lateral stem is allowed to develop to its first node, at which point a leaf develops as well as another secondary lateral stem. The secondary lateral stem is pruned out, leaving the first leaf on the original lateral stem as well as the primary leaf on the main stem. The reason for leaving this second leaf is to increase the leaf area of the canopy to both make better use of the increasing light levels and to provide shade for the developing fruit.

In May, a third leaf (two leaves on the primary lateral at each node) can be allowed to develop on plants that are in perimeter rows. These plants receive more light because of their position next to the walls, and the additional leaves provide the required shading to the fruit as well as increased photosynthetic area. Care has to be taken when pruning to ensure the main stem is not "blinded," that the growing point of the main stem is not pruned out. If this situation occurs, the main stem will not develop any further. The main approach to avoid blinding the main stem is to allow the lateral to develop 1.5 to 2.0 centimeters (0.5 to 1.0 inches) before pinching it out. This growth allows the lateral to be clearly identified and makes it easier to be very exact about what is being removed to ensure the main stem growing point is left intact.

It is important to keep the pruning current with the development of the plant. Once pruning falls behind, there really is no catching up without sacrificing some yield, as too much of the plant's resources were allowed to go into undesirable leaf and stem production.

Pruning is done using the fingers or small scissor cutters to ensure the precise removal of the laterals and to avoid any damage to the main stem or main stem growing point. When pruning the plants, use a powdered milk solution to dip hands into between each plant. The protein in the milk works to inactivate viruses that could potentially spread from plant to plant. The use of the milk solution should continue until June.

Flower and fruit set

The primary goal in managing the young pepper plants is to establish a strong vegetative plant on the sawdust bags. However, it is important to know when to target the first fruit set and start to establish the balance between stem and leaf production as well as fruit production. The presence of fruit will reduce vegetative growth as the balance is established. Pruning and training of the leaves and stems then allows for the matching of the vegetative growth with fruit growth. Once this balance is established, it is important to work to maintain the balance for continual, steady production throughout the season.

If the crop goes "out of balance," the production of fruit can occur in flushes, interspersed with periods of vegetative growth where growers have to work hard to direct the plants back into a generative, fruit-producing direction. Once the pepper crop establishes a pattern of production, i.e. flushes of fruit production, it is difficult to direct it away from this pattern to a more steady cycle of fruit production.

Flowering, fruit set and fruit size are related to the 24-hour mean temperature as well as to day/night temperature fluctuations. Fruit set is increased by low temperatures, but the fruit development may be affected by pollen infertility. The day/night temperature difference can be used to direct the plant to set flowers and fruit, while the 24-hour average temperature can be used to ensure proper fruit development in the shortest time.

The optimum temperature for flowering and fruit set in peppers is 16°C, while the optimum 24-hour temperature for yield is about 21°C. However, the day/night temperature difference is of secondary importance compared with the effect of the 24-hour mean temperature for fruit set, fruit development and the fruit growth period of sweet pepper.

Pepper flowers are small under high night temperatures and large under low night temperatures. The growth of malformed fruit is associated with temperature problems during pollination. Flattened fruit or "buttons" indicate insufficient pollination, which is associated with the development of very few seeds per fruit. The functioning of female flower organs is inhibited at low night temperatures (14°C or less), which gives rise to flattened fruit. The appearance of "button" pepper fruit in Alberta greenhouses is limited to early season fruit developed during the winter. This is the time of the year when providing precise heating to the "heads" of the plants would help improve flowering, fruit set, fruit development and fruit quality.

Figure 14. *Flower and fruit set.*

Pointed fruit, which develop to a size similar to normal blocky fruit, are probably a result of an imbalance of pepper plant growth regulators (hormones) in the developing fruit.

At high temperatures, 32 to 38°C, elongation of the style can occur with a resulting reduction in fruit set. Fruit set is known to be reduced at temperatures above 27°C and by low relative humidity. There is also evidence of progressive reduction in fruit size

associated with increasing light intensity during the high light summer months. Shading the greenhouse can offset some of the effects of high light intensity during a the summer months. Use a 10 per cent shading starting about the beginning of June.

The hot dry Alberta summers make it nearly impossible to maintain the optimum day-night and 24-hour temperature targets without the use of some form of evaporative cooling (pad and fan or mist systems). However, the plants generally do not have trouble continuing to set flowers under these conditions. Stressful summer conditions direct the plants to remain generative and can actually push the plants to be too generative. The plants have to be managed to maintain adequate leaf cover and balanced fruit load. These conditions are achieved by leaving more leaves on the plants and targeting about six fruit per stem. If too many fruit per stem are allowed to set, and the plant is not directing adequate resources to leaf development, the plant will "stall" and will not be able to fill the fruit, resulting in yield loss.

As the day/ night temperature difference is established one week after transplanting (while maintaining the 24-hour average temperature target of 20 to 21°C), the plants will be directed to set flowers, with the first flower developing at the "fork." The flower developing at the fork should be removed, with the first flower set and resulting fruit set targeted for the second node above the fork. After this flower sets, the flower at the third node is removed and the fourth node is left to develop. The flowers that follow at the fifth node and upwards are allowed to set freely. If the flower at the second node aborts, allow the third node to set a flower; if this flower sets, remove the flower at the fourth node and then allow all subsequent flowers to set (Figure 15).

Maintaining the root zone temperature at 20°C is also very important for the establishment of the plant balance. Lower root zone temperatures (approximately 15°C) direct the plants to remain vegetative and will increase flower abortion as well as the abortion of young fruit (Figure 16).

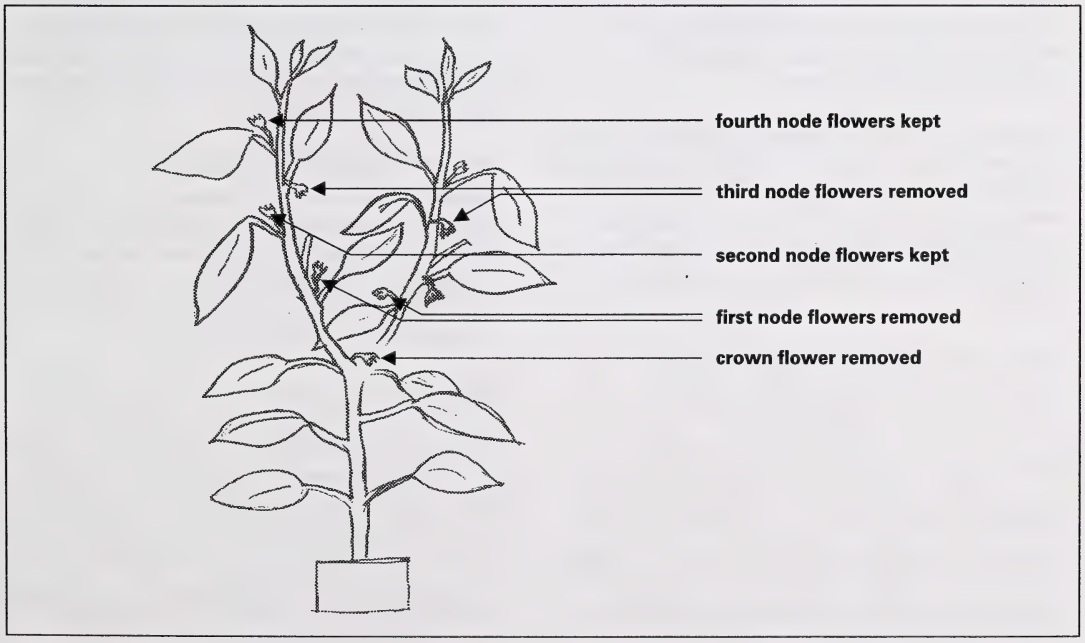


Figure 15. *General scheme for targeting the first flower and fruit set.*

Figure 16. Young fruit, just set.

Abortion of flowers and fruit is related to the rate of production of photosynthetic assimilates and the distribution of assimilate within the plant. That is, number of flowers and fruit creates a demand for plant resources, and if the plant cannot meet the demand due to low light levels, etc., high rates of abortion of newly formed fruit can occur. The influence of low light levels resulting in flower abortion is thought to result if light levels are low between the fifth and tenth day following the appearance of the flower bud.

Having heat close to the young fruit has been shown to enhance fruit development in tomatoes and would be beneficial for peppers. Using a height adjustable heating pipe to maintain 20°C near the top of the plant or "head" would improve flower set and fruit development during the cold winter months early in the season.

Unlike tomatoes, pepper flower pollination occurs successfully without any pollination assistance (assuming the correct temperature targets are established). Additional pollination assistance, bumble bees or "artificial" pollination, has been shown to improve flower set and the eventual yield and quality of the pepper fruit. But, it has also been shown that the beneficial effects of pollination appear related to the cultivar grown, with some but not all cultivars demonstrating this enhanced development of fruit in response to pollination. If bumblebees are used to aid pollination, it is important to manage the bees to ensure they do not visit the individual pepper flowers too aggressively, which can result in scarring of the developing pepper fruit.

Irrigation

For irrigation, follow the general recommendations outlined in the *Commercial Greenhouse Production* publication in the section called "Managing Fertilizer and Irrigation." Target 5 per cent overdrain early in the cycle, and increase overdrain up 30 per cent in summer. Increase the amount of water to meet the demands of the plant. If the plants have a light green "halo" at the growing point in the morning, they received adequate water during the previous day.

The root zone E.C. will rise if the volume of water is not adequate. Feed at an E.C. in the range of 2.5 to 3.0 mmho to maintain a root zone E.C. of 3.5 to 4.0 mmho. As the season progresses and light levels improve, increase the number of waterings during the day to keep pace with the increasing day lengths.

Night watering may be considered during the summer. Target the first watering of the day within half an hour of sunrise and the last watering of the day within about one to one and a half hours before sunset. Target the first overdrain for about 10:00 a.m.. Pepper plants can take up to 3.5 to 4.0 litres of water a day during the summer.

Harvesting and grading

Fruit set to harvest takes between seven and nine weeks. This time frame is longer during the low light periods of the year. The fruit is harvested at 85 to 90 per cent color, and a knife is used to make clean cuts on the peduncle (fruit stem). Care must be taken not to cut into adjacent fruit or stems.

Fruit is graded according to size, and the larger size peppers usually command a higher price (Table 1). The size potential of pepper fruit is determined by the cultivar, but the management of the crop determines whether or not the maximum size potential will be met for the greatest number of fruit picked. Fruit size, as with total crop yield, is a function of two factors: the management of the greenhouse environment and the plant handling that is done to establish and maintain optimal plant balance.

Table 1. Guide to Pepper Grade

Size (Fruit diameter in millimeters)	Grade
> 80 mm	Extra Large
70 - 79 mm	Large
60 - 69 mm	Medium
50 - 59 mm	Chopper

Fruit should be free from blemishes or cracks

Costs

Growers are always very cost conscious. Pepper production involves a number of costs, shown in detail in the costs and returns data in Table 2.

Table 2. Greenhouse Production Costs and Returns for Peppers***

	Total ($)	$/Sq. F
Greenhouse Production Area - 1998, Sq. Ft	**58,560**	
A. Gross Revenue	**535,824**	**9.15**
Operating Costs		
Growing Media, Seed/Cuttings	41,577.60	0.71
Fertilizer & Chemicals	18,153.60	0.31
Greenhouse Fuel	79,641.60	1.36
Power/Water/Telephone	18,868.03	0.34
Greenhouse Insurance	7,612.80	0.13
Building & Machinery Repairs	6,441.60	0.11
Auto Fuel & Repairs/Insurance & Registration	15,225.60	0.26
Property & Business Taxes	1,171.20	0.02
Accounting, Legal & Office supplies	3,513.60	0.06
Membership, Donations & Subscriptions	5,270.40	0.09
Travel, Advertising & Soil Testing	2,342.40	0.04
Marketing Costs & Freight	40,406.40	0.69
Interest on Operating Loan	1,756.80	0.03
Hired Labour/Insurance &Benefits	116,534.40	1.99
Miscellaneous costs	7,613.00	0.13
B. Total Operating Costs	**336,128.83**	**6.27**
Investment Costs		
Operator's Labour	38,064.00	0.65
Interest Costs	60,902.00	1.04
Depreciation	37,049.00	0.63
C. Total Investment Costs	**136,015.00**	**2.32**
D. Total Production Costs (B+C)	**502,144.00**	**8.58**
Return Over Operating Costs (A-B)	**169,695.00**	**2.90**
Return to Management (A-D)	**33,680.00**	**0.57**

Notes: (1) Most of the greenhouse operations are using biological control for pests
(2) Miscellaneous costs include bank service charges, equipment lease/rental, crop supplies and construction material, etc.
(3) Operator's labour is included under investment costs
(4) Return to management is excess of revenue over all expenses

*** Nabi Chaudary, 1998
Alberta Agriculture, Food and Rural Development

The Zen of Greenhouse Peppers

Greenhouse peppers can be a challenging crop to grow. Once the plants establish a pattern of growth, it can be difficult to manage them to go in another direction. For example, if the plants are strongly vegetative, it can take some time to direct the plants to be more generative, and vice versa. It is important to establish the proper balance in the plants as early as possible to set the stage for continuous, sustainable production and subsequent high yields.

Particular challenges with pepper production include setting and holding the first fruit. Fruit set is targeted at the second or third node above the fork where the plant breaks into two stems. The challenge here is that the young plant is generally strongly vegetative (a requirement for good establishment in the sawdust bag and eventual filling of fruit), and such plants tend to want to remain vegetative. By establishing the proper 24-hour average temperature of about 20 to 20.5°C, with a day temperature of 21°C and a night temperature reaching 16 to 17°C, and holding this regime, the plants will be directed to set and hold fruit.

The next challenge is to have an adequate fruit load established on the stems before the first fruit are picked. If the first fruit set and subsequent flowers do not set, all the plant energy goes towards vegetative growth when the first fruit are harvested. The plants will "race" to the supporting wire, resulting in a significant loss of yield.

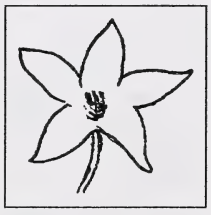
The crop will likely stay in balance to the end of the season once a good balance is established in the plants, maintaining about five to six developing fruit per stem (10 to 12 fruit/plant) at all times with fruit taking approximately seven weeks to mature. This schedule assumes no drastic changes in the management of the crop.

Plant Signals

As the season progresses, it is important to pay close attention to the plants. The following are a few signals the plants may exhibit and an explanation as to what the signals indicate.

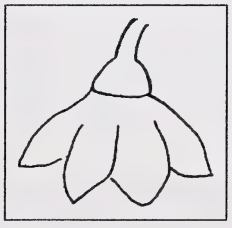
Flowers

Flowers upward facing, weak. The plant is too generative; reduce night temperature to drop the 24-hour average temperature by 1°C. This approach will direct the plant to be more vegetative. Weak flowers usually occur during the summer months, although they can show up earlier if the greenhouse is too warm.



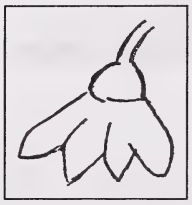
Weak, upright flower

Flowers large, bullish, thick peduncles, flowers opening downward. The plant is too vegetative. Raise the night temperature to bring the 24-hour average temperature up by 1 or 1.5°C. The fruit from these large flowers often abort or are deformed.



Bullish flower

Flowers opening downward, right-sized. Normal flowers, the Zen state.



Normal flower

Fruit

Fruit abortion. Most fruit abortion occurs within one week of fruit set and is related to the "unwillingness" of the plant to carry the fruit. The plant is either too vegetative and needs to be directed to set and hold fruit by raising the 24-hour average temperature up by 1°C, or it is too generative and is dropping young fruit because it is already carrying too much of a load. Direct these plants vegetatively by lowering the 24-hour average temperature 1 or 2°C.

Misshapen fruit, tails. Most problems with fruit shape are related to poor temperature conditions during flowering. The problems are usually seen when air temperatures fall below 14°C for periods over the course of a few days, primarily during the winter months. Lygus bugs can also cause fruit shape problems; the bugs feed by inserting their mouthparts into the very young peppers, much like mosquitoes feed on people. The damage becomes apparent when the fruit continues to develop and the damaged tissue tears open. Lygus bugs can even "top" the plant by killing the growing point.

Cracking/split fruit. Fine cracks on the skin, russeting, occurs when the relative humidity in the greenhouse rises above 85 per cent. Fruit splitting can occur as a result of high root pressures when the night air temperatures are cool and root zone temperatures are high. It is also important not to water too late in the day.

Sizing but not reaching mature color. Peppers reach mature size, but do not completely reach mature color over the entire fruit, even after eight weeks. This condition is thought to be related to lower 24-hour average temperatures. Raising the 24-hour average temperature 0.5°C should help correct this problem in the crop.

Premature fruit drop. Fruit mature to size but not yet to color, and premature abscission, or fruit drop, occurs. The problem is seen early in the season. It affects the first fruit to size and appears to be related to low boron levels in the feed. Growers who use sawdust as their growing media are reminded that they may have to feed higher amounts of boron, 0.9 ppm, rather than the standard 0.5 ppm.

Fruit reaching mature color but not sizing. Small fruit usually indicates a plant that is too generative, one that has put more resources into setting fruit and not enough resources into developing the leaf area required to fill the fruit. These plants also have very short internodes, have small leaves and appear stalled. Reduce the night temperature by 1 or 2°C to direct the plant to be more vegetative. Target internode lengths of approximately 6 to 7 centimeters. Remember that secondary fruit produced on laterals will always be smaller than primary fruit on the main stem.

Blossom end rot. This rot may appear at the blossom end or on the side of the fruit. Blossom end rot is due to either a calcium deficiency or reduced translocation of calcium to the fruit. It can result under conditions of lower transpiration or a shortage of water. A high E.C. in the root zone restricts the uptake of water. Maintain an active environment so the plants are transpiring. If the problem is not corrected, apply a spray of 400 ppm calcium chloride solution to the plants.

Sun scald. During the summer months under high solar radiation, any fruit exposed to direct sunlight can develop sun scald. The symptoms of sun scald appear similar to those due to blossom end rot. Ensure that adequate leaf cover is maintained to shade the fruit from direct sunlight.

Leaves

Turning over, underside of leaves face up. This leaf behavior is common when the plants are first set out into the production greenhouse and is also seen on established plants, usually in outside rows. The condition appears to be related to high vapour pressure deficits such as when transplants are moved from the nursery into conditions of lower relative humidity in the greenhouse.

Curling, from the edges in. This condition is seen primarily on older leaves, although some cultivars may have more of a tendency to exhibit this characteristic. It is not considered a problem. Excessive curling and twisting on the young growth can be an indication that herbicides have drifted into the greenhouse.

Interveinal chlorosis. As the leaf ages (over three months old), the tendency for developing interveinal chlorosis increases. A result of ageing and senescence, these leaves are no longer as active in the development of the plant and fruit. The plant can "mine" the leaf, removing mobile nutrients for use on other parts of the plant. This behavior is normal.

Interveinal chlorosis on the younger leaves can indicate a problem with the nutrient solution or that the root zone temperatures are exceeding 23°C. It is important to keep the root zone temperatures in the 19 - 22°C range.

Large leaves. Large leaves are a sign of a strong vegetative plant. The occurrence of large leaves is not a problem if the fruit set is also good.

Small leaves. Small leaf size indicates that the plant is generative, which should also be apparent by a heavy fruit set. The plant may be too generative if the fruit are taking too long to ripen and are undersized. As well as lowering the 24-hour average temperature, it is recommended that growers have about 20 ppm of ammonium nitrogen under summer conditions. This addition will help direct the plant to be more vegetative.

End of Season Cleanup

The end of season cleanup is necessary to help ensure the success of next year's crop. A thorough cleanup is an important component of the pest and disease management program as it can prevent or minimize the carry over of pest and disease problems into the next season.

All crop residue must be removed from the greenhouse and disposed of. Depending on the geographical area, facilities may exist to accept the crop residue for composting. The spent sawdust from the grow-bags could be a welcome addition to compost sites since much sawdust decomposition has already occurred during the growing season. Once the crop has been removed, increasing the greenhouse temperature to over 25°C for several days can increase the metabolic activity of any pests still in the greenhouse and can help cause them to die of starvation in the absence of their food source.

The interior of the greenhouse should be washed with a detergent solution using a pressure washer and then rinsed. The detergent will remove oily residues from the greenhouse and covering material. Following the rinse, a 10 per cent bleach solution can be applied to aid in disinfecting the greenhouse structure of any remaining pests and disease organisms. To avoid a chemical reaction between the bleach and the detergent, it is not recommended that the detergent and bleach be applied in the same operation. When pressure washing the greenhouse, ensure that all safety precautions are taken to prevent direct exposure to the bleach solution.

All greenhouse equipment should also be washed and disinfected. Dripper stakes and clips should be soaked overnight in a 10 per cent bleach solution and then rinsed.

The irrigation lines should be flushed with nitric or phosphoric acid at a pH of 1.6 to 1.7 (1 part acid to 50 parts water). Do not allow the acid solution to contact the pH electrode sensors or the E.C. sensors as they can be damaged. The acid solution should be allowed to sit in the lines for 24 hours, at which time the lines should be thoroughly rinsed with water to ensure that all the acid solution is removed.

CAUTION: Provide good ventilation through the greenhouse when flushing the lines with acid to avoid the build-up of fumes. Ensure the flushed water does not have a pH of below 5; otherwise, dangerous chlorine gas may form.

Steam Sterilize Rockwool Slabs

If rockwool slabs are used as the growing media instead of sawdust bags, the rockwool slabs can be used again for the upcoming crop. The reuse of rockwool slabs is both environmentally friendly and makes economic sense. Good quality slabs can be used for up to three years. Do not use slabs that have lost more than 10 per cent of their original height. This level of loss is an indication that the structure or "profile" of the slab has changed so much that the yield of subsequent plants grown can be reduced significantly.

Steam sterilization can ensure that disease organisms do not carry over into the next season. Slabs should be as dry as possible because dry slabs heat faster than wet slabs. If the crop has had tomato mosaic virus (TMV) or pepper mild mottle virus (PMMV), the slabs should be heated to 100°C and held at this temperature for 10 minutes; otherwise, the slabs should be heated to 75°C for 20 minutes. If the slabs are bagged and paletted, it takes five hours for the temperature to reach 100°C.

Pest and Disease Management

Successful crop production requires that crop pests and diseases be managed so that their effects on the plants are minimized. The management of crop diseases is directed at preventing the establishment of diseases and/or minimizing the development and spread of any diseases that do become established in the crop. Managing pest problems is directed at preventing the pest populations from becoming too large and uncontrollable. The presence of pests and diseases are a fact of life in crop production, and growers must use all available options and strategies to avoid serious pest and disease problems.

Integrated pest management (IPM) is a term used to describe an evolving process where cultural, biological and chemical controls are included in a holistic approach to pest and disease control. Key components of effective pest and disease control programs include the following:

- crop monitoring
- cultural control
- resistant cultivars
- biological control
- chemical control

Crop Monitoring

Crop monitoring is the continual surveillance to detect the presence of a pest or disease at the very early stages of development, before economic damage has occurred. Everyone involved in working the crop should be made aware of the common pest and disease problems and should know what to look for to detect problems in the crop. In addition to this general crop surveillance, dedicated crop monitoring should be included in the weekly work schedule. Blue sticky cards, placed throughout the crop, are a useful monitoring tool to help trap and detect pest problems before they become a problem. Yellow sticky cards are known to attract and catch some biological control agents, for example *Aphidius* sp.

Biological control agents can be released well in advance of any pest population explosion, thus allowing for the establishment of the control agents and the prevention of a serious pest problem.

Crop monitoring should begin when the crop is still on the seedling table or at the transplant stage (especially when transplants are obtained from another greenhouse, that is, purchased from a propagator). If transplants are being purchased from a propagator, it is important to be in contact with the propagator regarding any pest problems encountered during the production of the transplants.

It is also important to know what pest control measures, if any, were used to control the problems. Establish in advance what control measures are to be applied to the transplants at the propagator's before receiving them into the greenhouse. The concern is that any pesticides applied need to be compatible with the pest control programs, such as biological control programs, that will be used for the duration of the crop. Some growers may insist that only biological controls be used during the production of transplants and/or that biological control agents be introduced to the transplants as a preventive measure before the transplants are received.

Cultural Control

Cultural control involves providing the conditions that favour the growth, development and health of the crop, and wherever possible, providing conditions that work against pest and disease. Many disease-causing fungi and bacteria require the presence of free water or condensation on the plants to cause disease. High relative humidity promotes the development of disease, and maintaining the environment below 85 per cent relative humidity will help avoid disease problems. Ensuring proper ventilation and air movement within the crop canopy, as well as maintaining optimum plant spacing and a relatively open canopy, will ensure good air circulation and minimize the establishment of micro-climates that favour disease development. Proper contouring of the greenhouse floor will avoid the pooling of water, which contributes to localized high relative humidity.

Optimizing the greenhouse environment to favour plant development will ensure a strong, healthy plant, which is not only a prerequisite for high yields but will also result in plants better able to resist diseases and insect pests.

Good crop sanitation is another important component of successful cultural control. The plants must be pruned and maintained on schedule, and all crop debris should be removed promptly from the vicinity of the greenhouse. Immediately remove any weeds that happen to gain a foothold through gaps in the floor plastic, and repair the floor. Personal plants or "pet" plants should not be grown in the greenhouse. Weeds and "pet" plants can be both a source and a haven for pest and disease problems.

Pruning tools and other equipment should be cleaned and disinfected on a regular basis. Aprons or other clothing worn by the workers should be washed frequently. When a disease or pest problem area exists in the greenhouse, that area of the greenhouse should be worked last to avoid the spread of the disease or pests by the workers. In this situation, special care must be taken to disinfect tools and to clean clothing.

Maintain a 6 to 10 meter-wide buffer zone around the outside of the greenhouse by regularly mowing any weeds that grow in this zone. Plants in close proximity to the greenhouse can serve as reservoirs for the continual introduction of pests and diseases. Screening the air intake vents can also play an important part in excluding pests from the greenhouse. It is not enough to just screen off the intake vents because the screening restricts the air flow into the greenhouse. Make sure the surface area of the screening used is large enough so that it does not restrict the flow of air into the intake vents. Ensuring adequate air flow may require a screen chamber to be constructed over the vent.

Resistant Cultivars

Plant breeders have had considerable success in developing cultivars that contain genetic resistance or tolerance to diseases. When selecting the cultivars to be grown, it is important to consider the genetic resistance of the cultivars to the prevalent disease problems in the region.

The development of cultivars possessing genetic resistance to pests has been relatively unsuccessful; however, the techniques of genetic engineering have made inroads in conferring pest resistance to plants. Genetically modified, pest resistant plants may become available to greenhouse growers in future.

The development and use of genetically modified plants or genetically modified organisms (GMOs) is currently a contentious issue, and cultivars such as these may not be accepted by growers or consumers.

Biological Control

Biological control (or biocontrol) uses beneficial organisms, primarily predators and parasites, to control pest populations below economically significant levels. The goal is to establish a balance between the pest population and its parasites and predators, to keep the pest population under control. Complete eradication of the pest population is not the goal of biological control programs, as some pest organisms are required, so the parasites and predators are able to reproduce.

The greenhouse industry has a well established reputation for using biological pest control agents, more than any other crop production industry. The reason for this practice is, in part, due to the ability of greenhouse growers to manage the environment to favour the biological control agents. Another factor is the relatively limited number of pest species in greenhouses, as well as a general tolerance of greenhouse crops to leaf damage caused by these pests.

The high value of greenhouse produce is another reason why the use of biological controls is economical in greenhouse crops. The increased use of biological controls has led to a reduction in pesticide applications, giving the industry the lead in environmentally responsible, intensive crop production.

The effective biological control of diseases is a more difficult goal to reach and to date, has rarely been achieved. However, research in developing biological controls for greenhouse crop diseases is ongoing, and it is likely that biological control products for greenhouse diseases will be available in Canada in the near future.

The primary strategy of biological control for greenhouse plant diseases is to introduce fungal parasites to control populations of disease-causing fungi in the greenhouse environment so that they either cannot or have a reduced ability to infect the plants. Some of the promising biological control agents, for example fungi in the Genus *Trichoderma*, are also strong competitors of the disease-causing fungi such as *Botrytis cinerea*, and these agents can be used to protect wound sites to prevent *Botrytis* from colonizing the wound.

Chemical Control

Pesticides are valuable tools when used as a component of an integrated pest management program. Insecticides should be applied only in support of biological control programs, dealing with localized pest outbreaks in the crop that have escaped the biological control agents. When insecticides are used, care must be taken to ensure they are compatible with biological control agents and that there will be minimal long-term adverse residual effects on biological control programs. Fungicides are used only when a disease problem is detected.

Pesticides are often regarded as the controls of last resort because their misuse create high-profile environmental and food safety problems. Also, the application of some pesticides to a crop can cause stresses that reduce the productive life of the crop and can make the plants susceptible to other pests and diseases. Biological control agents are used to obtain a balance between pests and predators that does not threaten the productive yield of the crop, while the indiscriminate use of pesticides creates imbalance and uncertainty in the crop.

Biological Control of Greenhouse Sweet Pepper Pests

Descriptions of the common pests of greenhouse peppers are followed by a list of the biological control agents recommended for control. Pesticides are not discussed in this section. Pesticide recommendations can be obtained from your greenhouse crop production specialist.

Assessing Biological Control Agent Quality

Biological control agents are living organisms, and their ability to establish and control pest populations depends on their fitness. When ordering biological control agents, ask the supplier what to look for to help assess the quality of the agents when they arrive. A hand lens or magnifying glass is very useful when inspecting packages of biological control agents.

All packages of biological control agents should be inspected on arrival. Packages arriving during the winter should be checked immediately to ensure they have not been frozen or subjected to cold temperatures. The inside of the shipping cooler should not be cold. If the ice pack contained within the cooler is frozen solid, it is likely the entire package froze, and the biological controls have subsequently been damaged or killed. Packages received during the summer months should be cool inside. If the packages are hot inside, then the biological control agents may be damaged or killed.

Always release the biological control agents into the greenhouse as soon as possible after they are received. Follow the instructions provided with the package.

Aphids

The green peach aphid (*Myzus persicae*) is the most common aphid pest of greenhouse sweet peppers, but other aphid species can become a problem in greenhouse peppers (Figures 17 and 18). These other aphid species include:

- melon aphid (*Aphis gossypii*)
- potato aphid (*Macrosiphum euphorbiae*)
- foxglove aphid (*Aulacorthum solani*)

Figure 17. *Green peach aphids.*

Not all aphid biological control agents are equally effective on all aphid species, so it is necessary to be sure of the identity of the aphid species in question. All the species eventually develop winged forms.

Green peach aphids are usually light green, but can be pinkish or yellowish in the fall. The body is about 1.2 to 2.5 millimeters long and egg shaped. The winged forms can have black or brown-colored heads and black markings on the body.

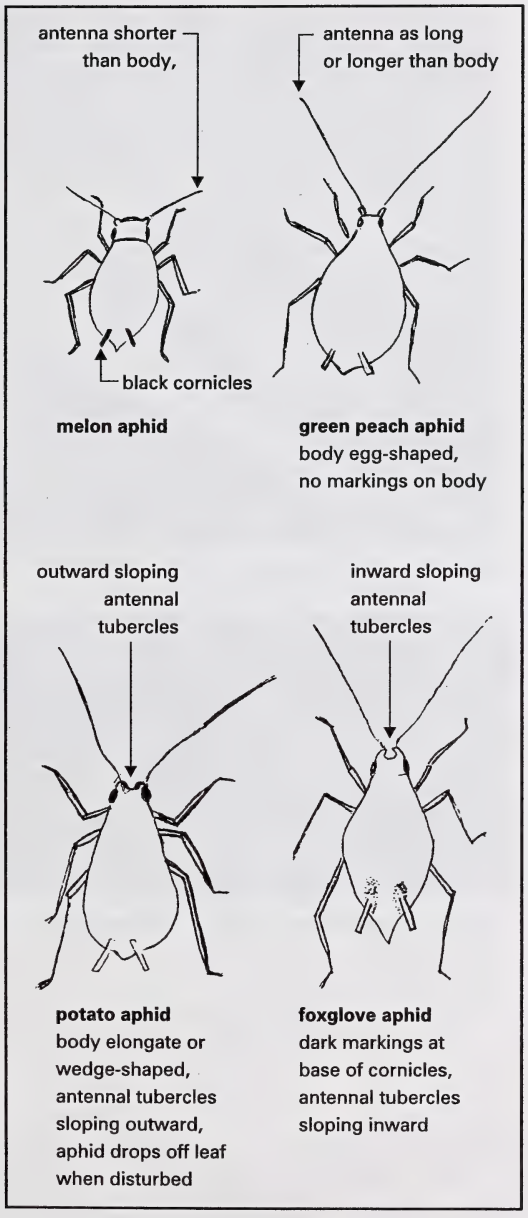

antenna shorter than body,
antenna as long or longer than body
black cornicles
melon aphid
green peach aphid
body egg-shaped, no markings on body
outward sloping antennal tubercles
inward sloping antennal tubercles
potato aphid
body elongate or wedge-shaped, antennal tubercles sloping outward, aphid drops off leaf when disturbed
foxglove aphid
dark markings at base of cornicles, antennal tubercles sloping inward

Figure 18. *Key to the wingless forms of the common aphids found in greenhouse peppers.*

Melon aphid adults are usually either black or green when there are just a few aphids present, but as the population grows and the aphids become crowded, the colors can range from olive green to yellowish green. Melon aphids are about the same size as green peach aphids, 1 to 3 millimeters long. These aphids can be distinguished from the other aphid species by their dark black cornicles and short antennae.

Potato aphids are quite large, 1.7 to 3.6 millimeters long, and the body is wedge-shaped and yellowish green to pink. The head has prominent antennal tubercles that are directed outwards. Potato aphids will drop off the leaves when disturbed.

Foxglove aphids are smaller than potato aphids, but larger than melon and green peach aphids. This aphid is a shiny light yellowish green to dark green with a pear-shaped body. The only markings on the bodies of wingless adults are darkish patches at the base of the cornicles.

Aphids can be present in the pepper crop very early, even while the plants are just in the seedling stage. These insect pests can come in on the transplants as well. Aphids feed by sucking the plant sap. Symptoms of aphid infestation include the development of sticky honeydew on the leaves and fruit. The presence of honeydew on the fruit means that the fruit must be washed before going to market. Sooty mold is often associated with the aphid honeydew. This mold uses the honeydew as a food source and grows to resemble a layer of "soot" on the leaves and fruit. The presence of sooty mold on the fruit also makes washing the fruit necessary. The growing points, young leaves, flowers and young leaves can be damaged and distorted, and in severe infestations, flower abortion can occur.

Control

Aphid control should be started in propagation with the introduction of parasitic wasps:

- *Aphidius matricariae* for green peach aphid
- *Aphidius colemani* for the melon aphid and green peach aphid
- *Aphidius ervi* for potato aphid
- *Aphelinus abdominalis* is effective against the potato and foxglove aphid

Parasitized aphids become silvery-brown and have a small exit hole at the back of the aphid where the parasite has emerged. The larvae of the midge *Aphidoletes aphidimyza* feed on most aphid species, but will not feed on gall-forming aphids. Aphid hot spots and population explosions may require introductions of lady beetle species, such as *Harmonia axyridis*, the Asian lady beetle, and large scale introductions of *Hippodamia convergens*.

Introductions of these predators and parasites may have to continue throughout the entire season. For best results, always use a combination of aphid predators and parasites. Consult your local supplier for information and recommendations on release rates.

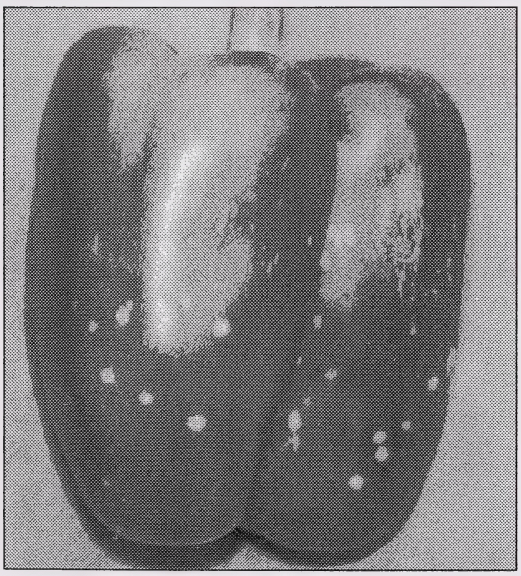


Figure 19. *White spots on pepper fruit caused by aphids feeding on the fruit bud when it was still very young.*

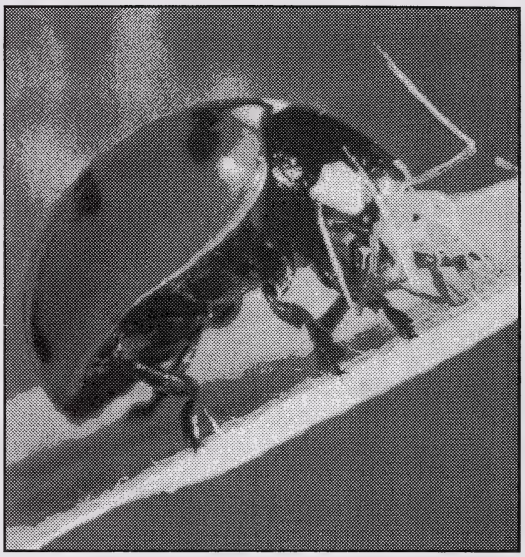


Figure 20. *A lady beetle adult consuming an aphid.*

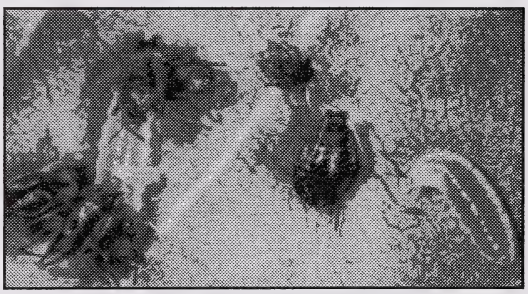


Figure 21. *Aphidoletes midge larvae feeding on aphids*

Two-spotted Spider Mite

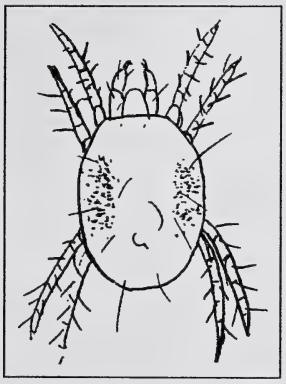


Figure 22. *Two-spotted spider mite.*

The two-spotted spider mite *(Tetranychus urticae)* is a common pest of a number of greenhouse crops. Typical symptoms of two-spotted spider mite infestations include speckling of leaves and fine webbing on the underside of affected leaves. As the spider mite population increases, the leaves become brittle and brown, the amount of webbing on the leaves becomes very prominent and the mites can be seen milling about on the webs. It is very easy for the two-spotted spider mites to be "picked-up" on workers' clothing and transported throughout the crop.

As the season progresses into fall, female two-spotted spider mites develop a bright orange-reddish color as they prepare for the winter. The female mites seek shelter in crevices throughout the greenhouse, and a thorough end-of-season pressure wash cleanup is necessary to minimize the number of females that survive to the next crop.

Control

Effective biological control of the two-spotted spider mite is obtained by introducing the predatory mite *Phytoseiulus persimilis* as soon as two-spotted spider mites are detected in the crop. *P. persimilis* does well in the pepper canopy, and once established throughout the greenhouse, this predator controls the spider mite population for the remainder of the season. The mites *Amblyseius fallacis* and *Amblyseius californicus* are closely related to *P. persimilis*. This related species establishes well and gives better control under low density mite situations, but should be used along with *P. persimilis*.

Thrips

Two species of thrips are common pests in greenhouse vegetable crops: the western flower thrips (*Franliniella occindentalis*) and the onion thrips (*Thrips tabaci*). Thrips feed by opening wounds on the plant surface and then sucking out the contents of the plant cells. The feeding results in small whitish streaks on the leaves and fruit and can cause distortions in the young, developing fruit.

Control

Adult thrips congregate in the flowers, and regular monitoring of the flowers will allow for the early detection of thrips. Yellow and/or blue sticky traps placed throughout the crop, as with the other insect pests, will help in the early detection of thrips infestations. Avoid using yellow traps if *Aphidius sp.* are being used for the control of aphids in the crop. *Aphidius sp.* are also attracted to yellow sticky cards.

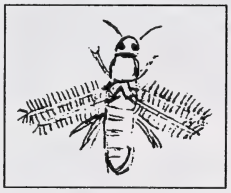


Figure 23. *Thrips.*

In addition to causing direct feeding damage and the resultant yield loss, both thrips species are vectors of Tomato Spotted Wilt Virus (TSWV), which can be a serious disease problem in peppers and tomatoes. One of the main control measures for minimizing the spread and infection of TSWV within the crop is to control the thrips vectors.

A number of predators are available for biological control of thrips: predatory mites *Amblyseius degenerans, Amblyseius cucumeris, Hypoaspis miles* and *Hypoaspis aculeifer* as well as predatory bugs, *Orius insidiosis* and other *Orius* species.

Loopers and Caterpillars

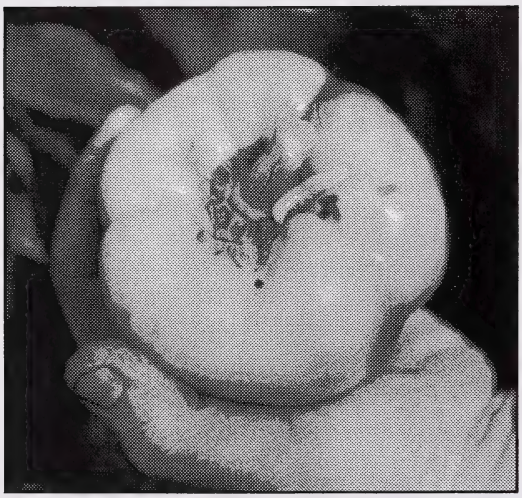


Figure 24. Looper on a pepper fruit.

At least two species of loopers have been associated with problems in Alberta greenhouse pepper crops. The cabbage looper, *Trichoplusia ni*, is the most common, while the alfalfa looper, *Autographa californica*, is an occasional problem. The damage is caused by the larval stages, which can reach 2.5 to 3.5 centimeters in length depending on the species. The cabbage looper is the larger of the two species in the final larval stage.

The larva are a light green with whitish stripes along the length of their bodies. The larvae feed on foliage and fruit. Fruit damage consists of holes in the fruit, accompanied by frass on and around the calyx. As the loopers reach their mature size, the amount of feeding damage can be considerable.

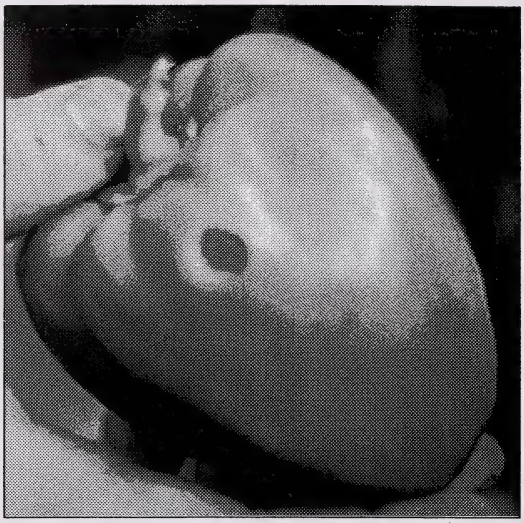


Figure 25. Looper feeding damage on a pepper fruit.

Loopers generally enter the greenhouse through vents and other openings as adult moths, which then lay eggs on the plants. The eggs hatch and the larval or looper stages begin feeding. They complete their life cycle in about 20 days. As a result, a number of generations can be completed in the crop if no control measures are taken. Loopers overwinter as pupae and can overwinter inside the greenhouse. When the greenhouse enters the new production cycle, the moths emerge, mate and begin egg-laying in the new crop.

Control

Screening intake vents will help prevent adult moths from entering the greenhouse. Pheromone traps can be used to detect the presence of adult moths in and around the greenhouse. These traps can be an indicator for when to introduce biocontrol agents. Ultra-violet light traps are also used to catch adult moths.

The egg parasite *Trichogramma brassicae* should be released as soon as adults are detected. The parasite *Cotesia magriniventris* should also be introduced. This parasite prefers to attack young loopers.

Bacillus thuringiensis (B.T.) can also be used as part of the biocontrol program. B.T. is a microbial biocontrol agent that is activated once the loopers consume plant material that has been sprayed with B.T. Also, since the loopers are quite large, they can be removed by hand when they are found in the crop.

Figure 26. *Looper damage on pepper leaves.*

Whitefly

The greenhouse whitefly (*Trialeurodes vaporariorum*) is a common and serious pest in greenhouse crops in Canada. However, it is rarely a problem on greenhouse sweet pepper. A second whitefly species, the sweet potato whitefly (*Bemesia tabaci*) has been found in some greenhouses in British Columbia. Of the two whitefly species, the sweet potato whitefly is more difficult to control.

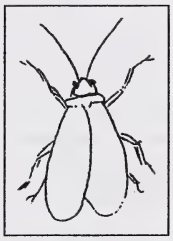


Figure 27. *Greenhouse whitefly.*

Greenhouse whitefly adults are about 2 millimeters long and congregate on the undersides of the leaves. They usually fly short distances when disturbed. Whitefly nymphs are clear, have flattened scales about 1 millimeter long at their largest size and are also found on the underside of the leaves. The sweet potato whitefly is smaller than the greenhouse whitefly and has a more yellowish color.

Whitefly damage the plant by sucking sap from the leaves. Large infestations can cause leaf yellowing and a general decline in the plant. Sooty mold is commonly found in association with whitefly. As with aphids, whitefly feeding also results in honeydew formation, which can reduce fruit quality. The presence of the honeydew and sooty mold can necessitate that the fruit be washed before going to market. The presence of sooty mold on the leaves can reduce the productivity of the leaf by reducing the amount of light reaching the leaf surface.

Control

The parasitic wasps *Encarsia formosa* and *Eretmocerus eremicus* are effective against whitefly. Parasitized whitefly scale become yellow or black, depending on the parasite. Scale parasitized by *Encarsia formosa* is black. *Delphastus pusillus* is a small beetle that feeds on whitefly eggs and is ideal for complementing *Encarsia* and *Eretmocerus*.

Fungus Gnats

Fungus gnats are commonly found in practically all greenhouse crops. These gnats are an indicator of moist conditions in the greenhouse, and populations generally grow to be quite large early in the year or whenever there is pooling of water on the greenhouse floor.

Adult fungus gnats range from 2 to 3 millimeters in length, while the larvae are 4 to 5 millimeters long. The larvae of the fungus gnats are the damaging stage and feed on the plant roots. These gnats are not generally a problem in greenhouse tomato and pepper, but can be a serious concern in cucumbers, especially with young plants.

Affected plants develop slowly and may eventually collapse if too much of the root system has been damaged. There is evidence that fungus gnat adults may transport root rot fungi such as *Pythium sp.* and *Fusarium sp.* from plant to plant, contributing to the spread of disease caused by these fungi.

Fungus gnats are often confused with shore flies, as both are common in the greenhouse under wet conditions. Shore flies are slightly larger than fungus gnats and look like scaled-down versions of house flies, while fungus gnats look more like tiny mosquitos that don't bite (Figure 28).

***Figure 28.** Fungus gnat.*

Control

Biological control of fungus gnats is obtained through the use of predatory mites *Hypoaspis miles* and most recently, *Hypoaspis aculeifer*. Both these predatory mites also have activity against thrips larvae that move to the base of the plants to pupate. Nematode parasites in the genus *Steinernema* are applied as a drench to the root zone. These parasites kill the fungus gnat larvae by penetrating the larvae and consuming them from the inside.

Lygus bugs

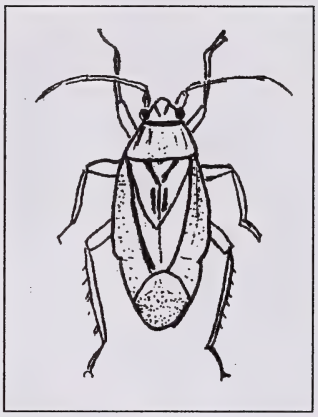


***Figure 29.** Lygus bug.*

Lygus bugs (*Lygus spp.*) are common pests of field crops in Alberta, particularly alfalfa, canola and strawberry. These pests have increasingly become a concern in greenhouse vegetable crops. A number of species within the genus can become pests in the greenhouse including *Lygus lineolaris*. When nearby alfalfa or canola fields are cut or harvested, large numbers of Lygus bugs can be displaced and move into the greenhouse. Lygus bugs can enter the greenhouse through unscreened vents.

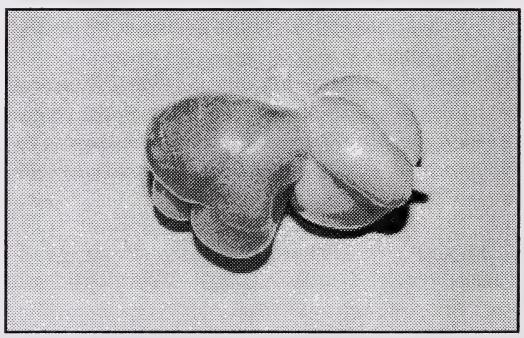


***Figure 30.** Malformed fruit caused by Lygus bug feeding injury when the fruit was in the very young "bud" stage.*

Adult Lygus bugs can reach 5 to 6 millimeters in length and can range in color from green to brown with mottled black markings. Once in the greenhouse, Lygus bugs can continue their life cycle and establish a population within the greenhouse. Both the adults and nymphs feed on plant juices through piercing and sucking mouthparts. The bugs like to feed on the plants at the growing points and can damage the developing flower bud, which results in malformed fruit.

Control

Lygus bugs are relatively large, fast-moving insects that can be difficult to control with biological control agents. *Orius* and *Deraeocoris* will feed on Lygus bugs. Preventing the entry of Lygus bugs into the greenhouse by screening the vents offers the best prospect for controlling this pest.

Earwigs

The European earwig (*Forficula auricularia*) can be quite common in greenhouses. These insects are brown and about 10 to 15 millimeters long. They are easily identified by the presence of distinctive "cerci," or appendages located at the back end of the insect. In the male earwigs, the cerci resemble pincers, whereas the cerci are almost straight on female earwigs. Earwigs are often found under the sawdust bags or rockwool slabs, or they may be hiding in other dark, moist, protected areas. Earwigs are nocturnal and feed on a variety of things, including plants and other insects.

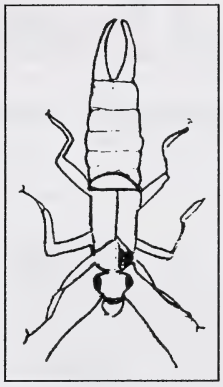


***Figure 31.** Earwig.*

Earwigs have occasionally become a problem in greenhouse sweet pepper crops by moving into the crop canopy and damaging pepper fruit located up to 1 meter off the floor. The earwigs burrow into the fruit at the calyx, causing damage similar to that caused by loopers. Cutting the fruit open often reveals a mature earwig. The holes in the fruit and the associated frass render the fruit unfit for market.

Control

These insects can be controlled by trapping them when they are still on the greenhouse floor, before they move into the crop canopy. Commercial traps and baits are available.

Diseases of Sweet Pepper

Fungal Diseases

A number of fungal diseases routinely attack greenhouse peper plants. These fungal diseases include damping-off, pythium crown and root rot, fusarium stem and foot rot, gray mold and powdery mildew.

Damping-off

Damping-off is a disease of seedlings and occurs on the seeding table when the young plants are just beginning to grow. The disease is caused by a number of species of *Pythium* as well as *Rhizoctonia solani*. If the disease attacks the young plants as they are just emerging from the seed, the symptoms of this pre-emergent damping-off are simply seen as areas where no seedlings have emerged. Damping-off in young, emerged seedlings is seen as a toppling over of the seedlings as the root systems are destroyed by the fungi. It is possible for some plants to be affected by these fungi and still develop into mature plants. If these plants are stressed later in the season, the fungi can begin to progress in the plants, causing a root rot that can eventually kill the mature plant.

Damping-off is not common when seedlings are grown in inert media such as rockwool; however, the disease is more common in soil-based media. The disease is seen more frequently where greenhouse sanitation practices are poor or where growing conditions, i.e. soil temperature, watering etc., are not optimal, and the young plants are stressed.

As commercial greenhouse vegetable seedlings and transplants are grown in rockwool, under optimal conditions with proper plant spacing, this disease is generally of minor importance. However, if the young plants are exposed to stress conditions, particularly conditions of cold or excessively moist root zones, then the disease can occur.

The best control for this disease is prevention, which is achieved by using high quality, fresh seed and by maintaining optimal growing conditions for the young plants.

Pythium crown and root rot

Pythium crown and root rot caused by a number of *Pythium spp.* is not common in greenhouse peppers. However, it can occur as an extension of an early damping-off problem in the seedlings or as a result of stressful conditions in the greenhouse at transplanting. Transplants infected by *Pythium* spp. develop slowly, are slow to root into and establish on the sawdust bags, and in extreme circumstances, will wilt and slowly die.

The early stage of the crop cycle often determines the success of the entire year. It is important to go into the production cycle with strong, well established plants. The best method for the control of Pythium root rot is to ensure that optimal growing conditions, particularly root zone temperatures and watering, are maintained.

Fusarium stem and fruit rot

The appearance of soft, dark brown or black lesions on the stems at nodes or wound sites are symptoms of Fusarium stem and fruit rot caused by *Fusarium solani*. Black, water-soaked lesions may also develop around the calyx, eventually spreading down the sides of the fruit. Under conditions of high humidity, the fungal mycelium can be quite apparent on the lesions.

Good sanitation practices are key factors in preventing fusarium stem and fruit rot. Infected plants should be carefully removed from the greenhouse and buried in a landfill. Maintain good air circulation in the greenhouse, and avoid conditions where the relative humidity rises above 85 per cent. Avoid wounding the fruit and/or causing excessive wounding to the stems.

Gray mold

Gray mold, caused by the fungus *Botrytis cinerea*, is a common disease of greenhouse crops grown under conditions of high humidity and poor air circulation. The fungus enters the plant from wound sites, and olive-green lesions develop that can eventually girdle the stem, causing the plant to die. Fruit infections commonly begin at the calyx or at wound sites.

To prevent gray mold, ensure good air circulation within the crop, maintain the relative humidity in the greenhouse below 85 per cent and avoid the formation of free water on the plants and fruit.

Powdery mildew

Powdery mildew of greenhouse pepper, caused by *Leveillula taurica*, is not a common problem in Canada. The first report of this disease in Canada was in 1999 in two separate greenhouse locations in Leamington and Vineland, Ontario. Yield losses of 10 to 15 per cent were associated with the disease in these greenhouses.

Spots with a white powdery coating develop on the lower surface of the leaves, and a slight chlorosis of the upper leaf surface is associated with the spots.

Viral Diseases

Many different viruses can attack pepper plants. These include pepper mild mottle virus, tobacco mosaic virus, tomato spotted wilt virus and the tomato mosaic virus.

Pepper mild mottle virus (PMMV)

Pepper mild mottle virus occurs practically everywhere that pepper is grown (Figure 32). It was first reported in Canada on field grown peppers in 1985. The first confirmed report of this virus in Alberta greenhouse sweet peppers was in 1998.

The virus is difficult to detect in the greenhouse until the plants begin to bear fruit. Leaf symptoms are easily mistaken for other problems, such as magnesium and manganese deficiencies. As the disease progresses in the plants, the new growth can be distinctly stunted and will show a clear mosaic pattern of yellow and green. Fruit symptoms often occur well in advance of the stunting symptoms. These symptoms include the development of obvious bumps on the fruit as well as color streaking and green spotting as the fruit matures to color. Infected fruit tend to have pointed ends and may also develop sunken brown areas on the surface.

Figure 32. *Pepper mild mottle virus symptoms.*

The routine use of skim milk (100 gms/Liter) as a dip for workers' hands while handling the plants acts to prevent any potential spread of the virus in the crop. The protein in skim milk binds to the virus and inactivates it.

The virus is very stable in plant sap, and it is easily spread from plant to plant. Once the plants begin to bear fruit, PMMV infected plants are fairly easy to recognize from symptoms on the fruit.

Infected plants should be carefully removed and destroyed as the virus can survive in dry plant debris for up to 25 years. If all plants bear normal fruit, dipping the hands in skim milk can be discontinued.

Pepper mild mottle virus enters the greenhouse primarily on infected seed, transplants, plant sap and plant debris. The virus is not known to be spread by insects, but is very easily spread by the routine handling of the young plants, especially at

transplanting. Many other plants in the Solanaceae family are susceptible, but tomato is not a host of PMMV.

Pepper mild mottle virus is related to tobacco mosaic virus (TMV), and pepper cultivars with TM resistance also have a level of resistance to PMMV.

Tobacco mosaic virus (TMV)

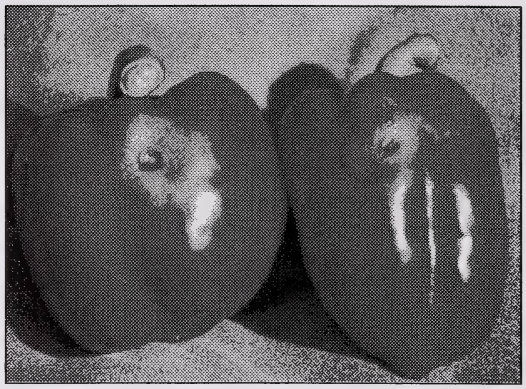
Tobacco mosaic virus is not a common disease problem in Canada, although it occurs on greenhouse peppers throughout the world. The symptoms of infection first appear on the leaf as a necrosis along the main veins accompanied by wilting and leaf drop. New growth on the plants may show mosaic symptoms as well as distorted growth.

To control this virus, use disease-free seed and ensure that resistant cultivars are grown. Use a skim milk dip for hands when handling the plants, and remove and destroy any infected plants that develop early in the season. Mature plants can be symptomless carriers of the virus and may escape detection later in the season.

Tomato spotted wilt virus (TSWV)

Tomato spotted wilt virus has a wide host range, affecting approximately 300 species in 34 families of plants. The virus is spread primarily by thrips, particularly the western flower thrips (*Frankliniella occidentalis*) and will only become a significant problem in greenhouse pepper crops if the thrips vector is present.

Symptoms of infection on the leaves include blackish-brown circular spots or tan spots bordered by a black margin (Figure 33). Symptoms on ripening fruit are quite dramatic, with orange to yellow spots surrounded by a green margin, or green spots on a background of the ripe fruit color of red, yellow or orange. Not all fruit from infected plants will develop symptoms. Experience in Alberta pepper greenhouses has shown that only about one-third of the fruit from infected plants will develop symptoms.



[Photo courtesy of Clive Schaupmeyer]

***Figure 33.** Tomato spotted wilt virus symptoms.*

Control of this virus is achieved by controlling the thrips vector. Thrips biocontrol programs should be started at the beginning of the season. Weeds should be kept under strict control as they can serve to harbour both the thrips vector and the virus. Maintaining a 6 meter weed-free buffer zone around the greenhouse will help prevent the introduction of thrips into the greenhouse, as well as prevent the establishment of virus-infected weed plants around the greenhouse. Close growing weed plants could serve as a source of the virus. Avoid having any ornamental plants in the greenhouse as they can also become reservoirs for the virus.

Tomato mosaic virus (ToMV)

Tomato mosaic virus is not a common problem in greenhouse peppers and causes symptoms very similar to those caused by tobacco mosaic virus.

Control measures are the same as for tobacco mosaic virus. Use disease-free seed, and remove and destroy infected plants.

Physiological Disorders

Blossom end rot

Blossom end rot (BER) is a common disorder of greenhouse peppers, with the symptoms occurring on the pepper fruit (Figure 34). The disorder is associated with a number of environmental stress triggers as well as a calcium deficiency. Any condition

that causes water stress or a reduction in transpiration, and resultant movement of nutrients through the plants, can bring on symptoms. Underwatering, fluctuating water conditions from dry to wet to dry, damage to the root system, and high E.C. in the root zone can all cause BER.

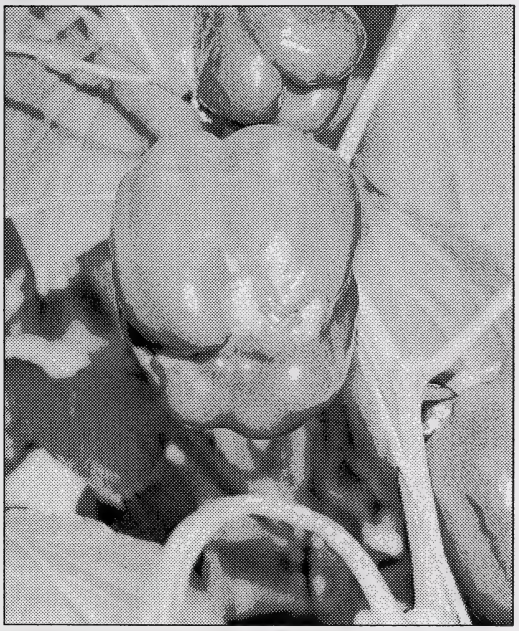


Figure 34. *Blossom end rot.*

An actual calcium deficiency to the plant is rarely the primary cause of the disorder because BER can develop when adequate levels of calcium are being fed to the plants. The environmental factors that can trigger the disorder interfere with the movement of calcium within the plant, causing less calcium to reach the fruit. Some cultivars are more prone to this disorder than others.

Symptoms of BER begin as soft spots on the fruit that develop into sunken, tan-brown lesions with a very distinct border between affected and healthy tissue. The spots usually occur on the bottom third of the fruit and are not strictly confined to the bottom, or blossom end, of the fruit. Affected fruit cannot be marketed.

Control of this disorder is achieved by avoiding conditions of moisture stress or conditions of reduced transpiration in the crop, by ensuring that the plants receive adequate water and that vapor pressure deficit (VPD) targets are met. Weekly foliar applications of calcium chloride (400 ppm) can have a significant effect on reducing the amount of BER.

Sunscald

Symptoms of sunscald on the pepper fruit are very similar to those for blossom end rot (Figure 35). Soft, tan-coloured, sunken lesions develop on fruit exposed to direct sunlight. It is important to adjust pruning practices to ensure that all fruit are shaded from direct sunlight. Applying shading to the greenhouse during the summer months will also help reduce the incidence of sunscald.

Figure 35. *Sunscald.*

Temperatures of exposed fruit can often be 10°C higher than shaded fruit, reaching over 35°C during the midday of a typical hot, sunny Alberta afternoon. These extreme temperatures in exposed fruit can be reached even when air temperatures in the greenhouse are maintained below 27°C. Fruit temperatures over 35°C must be avoided.

Fruit cracks

This condition is characterized by the appearance of very fine, superficial cracks on the surface of the pepper fruit, which give a rough texture to the fruit. The development of these cracks is associated with sudden changes in the growth rate of the individual fruit. The appearance of fruit cracks can follow periods of high relative humidity (over 85 per cent), changes from hot, sunny weather to cool, cloudy weather or vice versa. Maintaining a consistent, optimized growing environment is the best way to prevent fruit cracks from developing.

Fruit splitting

The development of large cracks in the fruit is a direct response to high root pressure. Factors that contribute to the development of high root pressure directly affect fruit splitting. Ensure that optimal VPD targets are met at all times. Adjust the timing of the last watering in the day so as not to water too late. Eliminate any night watering cycles.

Fruit spots

The appearance of small white dots below the surface of the pepper fruit is associated with excess calcium levels in the fruit and the subsequent formation of calcium oxalate crystals. Conditions that promote high root pressure will also favor the development of fruit spots.

Misshapen fruit

The development of misshapen fruit is generally associated with sub-optimal growing conditions at flowering and pollination, which result in poor flower development or poor pollination. The section on flower and fruit set in this publication discusses some of the common causes of misshapen fruit, which include temperatures being either too cool or too warm. Ensuring that all environmental targets are met and maintained will reduce or eliminate the development of misshapen fruit (Figure 36).

Figure 36. *"Wings" on pepper fruit due to low temperatures during pollination.*

Internal growths

If growths develop within the pepper, they usually appear early in the cropping cycle, generally on the first fruit set. This situation results from abnormal tissue development in the honey gland of the fruit.

Conclusion

Although bell peppers can be challenging to grow, they are becoming a popular greenhouse crop for Alberta greenhouse growers. Because of these challenges, growers would do well to have a greenhouse structure with excellent environmental controls to ensure the best chance of a successful crop.

For further information on successful commercial greenhouse growing, check out Alberta Agriculture's *Commercial Greenhouse Production in Alberta*.

Appendix 1. Effect of Pesticides on Biological Control Agents*

Trade Name	Common Name	*Encarsia Aphidius*	*Persimilis Follicis*	*Cucumeris Hypoaspis*[1] *degenerans*	*Aphidoletes*	*Orius Harmonia Delphastus*
Admiral*	pyriproxifen	H(35)N	I	I	I	S
Admire*	imidacloprid	H(21)N	S	S	H(20)	H(30)
Afugan	pyrazofos	H(21)	S(0)	H(7)	H(21)	H(21)
Agrimycin	streptomycin	S	S	S	S	S
Ambush*	permethrin	H(56)N	H(56)	H(56)	H(56)	H(56)
Apex	methoprene	S	S	S	S	?
Applaud	buprofezin	H(3)	I(0)	S	H(7)	H(3)
Avid*	abamectin	H(21)R	H(14)	H(14)	H(21)	H(21)
Azatin	azadarachtin	?	S	?	?	S
B-Nine	daminozide	S	S	S	S	?
Baygon	propoxur	H(60)N	H(14)	H(42)	H	H
Basamid	dazomet	S	S	S	S	S
Benlate, S	benomyl	S	H(14)	H(14)	S	H
Botran	DCNA	S	S	S	S	S
Bravo	chlorothalonil	S	S	I	S	S
Captan	captan	S	S	S	S	S
Citation	cyromazine	S	S	S	H	I
Cygon*	dimethoate	H(60)N	H(60)	H(60)	H(14)	H
Daconil	chlorothalonil	S	S	I	S	S
DDVP	dichlorvos	H(7)	H(3)	H(3)	H(3)	H(7)
Decis*	deltamethrin	H(56)N	H(56)	H(56)	H(56)	H(56)

* Information provided by Julie Sisson, Pest Mangement Regulatory Agency, Lethbridge, Alberta.

Legend

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Appendix 1. Effect of Pesticides on Biological Control Agents* (cont'd)

Trade Name	Common Name	*Encarsia Aphidius*	*Persimilis Fallicis*	*Cucumeris Hypoaspis*[1] *degenerans*	*Aphidoletes*	*Orius Harmonia Delphastus*
Derris	rotenone	H(42)N	H	H	H(14)	H
Diazinon*	diazinon	H(42)N	I(7)	H(21)	H(42)	I
Dibrom F	naled	H(7)	H(3)	H(3)	H(7)	H(3)
Dimilin	diflubenzuron	S	S	S	S	S
Dipel	*Bacillus Thuringiensis*	I	S	S	I	I
Dithane	Maneb	I	S	S	I	H
Dursban	chlorpyrifos	H(28)N	H(3)	H(14)	H(28)	H(28)
Dyno-mite	pyridaben	H(29)N	H	H	H(28)	H(14)
Enstar	kinoprene	I	I	I	I	I
Epsom salts	MgS04	S	S	S	S	S
Exotherm	chlorothalonil	I(7)	S	S	S	S
Fixed copper	copper	I(7)	S	S	S	S
Formalan	formaldehyde	H	H	H	H	H
Fungaflor	imazalil	S	H(3)	S	H(3)	S
Gardona*	tetrachlorvinÑphos	H(56)	I	H(42)	H(42)	H
Insecticidal-soap	fatty acid salts	H(0)	H(0)	H(0)	H(0)	H(0)
Impower*	imidacloprid	H(21)N	S	S	H(21)	H(21)
Karathane	dinocap	H(7)	S	I	H(7)	?
Kelthane	dicofol	H(7)	I(14)	H(30)	H(4)	I
Kumulus	sulphur	H(28)N	I(7)	I(7)	I	I
Lannate*	methomyl	H(48)N	H(21)	H(42)	H(56)	H(56)

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Appendix 1. Effect of Pesticides on Biological Control Agents* (cont'd)

Trade Name	Common Name	*Encarsia Aphidius*	*Persimilis Fallicis*	*Cucumeris Hypoaspis*[1] *degenerans*	*Aphidoletes*	*Orius Harmonia Delphastus*
Lindane*	lindane	H(56)N	H(42)	H(42)	H(56)	H
Lorsban	chlorpyrifos-methyl	H(42)N	H(7)	H(42)	H(7)	H
Malathion*	malathion	H(56)N	I(7)	H(56)	I(20)	H
Manzate	mancozeb	I	I	S	S	S
Maltatox	dodemorph	I(7)	S	I(7)	I	I
M-Systox-R*	oxydemeton methyl	H(56)N	H(7)	H	H	?
Micro-Niasul	sulphur	H(7)	I	I	I	I
Mitac	amitraz	H(21)N	H(21)	H(21)	H(14)	I(21)
Morestan	oxythiioquinox	I	H(14)	H(14)	I	?
Monitor*	methamidophos	H(28)N	H(56)	H(20)	H(21)	H(21)
Nicotine	nicotine	I(7)	H(7)	H(7)	H(I)	H
Nimrod	bupirimate	S	I(4)	S	S	I(0)
Nova	mycobutanil	S	S	S	S	I
Oil	refined oils	H(0)	H(0)	H(0)	H(0)	H(0)
Omite	propargite	I(7)		H	I	I
Orthene*	acephate	H(56)N	H(14)	H(56)	H(56)	H(42)
Parathion F*	parathion	H(56)N	I(5)	H(42)	H(56)	H
Phosdrin	mevinphos	H(7)	I(7)	H(7)	H(7)	H
Pirliss	pirimicarb	I(7)	I	I	H(7)	I(3)
Plantfune 103*	sulfotep	H(70)N	H(70)	H(70)	H(70)	H
Pyrethrum	pyrethrins	H(7)	H(7)	H(7)	H(7)	I

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Appendix 1. Effect of Pesticides on Biological Control Agents* (cont'd)

Trade Name	Common Name	*Encarsia*	*Aphidius* / *Persimilis* / *Fallicis*	*Cucumeris* / *Hypoaspis*[1] / *degenerans*	*Aphidoletes*	*Orius* / *Harmonia* / *Delphastus*
Ridomil	metalaxyl	S	I	I	S	?
Rovral	iprodione	S	S	S	S	S
Rubigan	fenarimol	S	S	S	?	S
Sevin*	carbaryl	H(28)N	H(14)	H(30)	H(30)	H
Sulfur F	sulphur	H(28)N	S	I(7)	I	I
Sulfur	sulphur	I	I(7)	I(7)	I	?
Temik*	aldicarb	H(49)N	H(21)	H(21)	H(49)	H
Thiodan	endosulfan	H(4)	H(14)	H(4)	H(14)	H
Thiram	thiram	I(14)	I(2)	I(2)	I(2)	I
Trumpet	bendiocarb	H(21)N	H(21)	H(21)	H(21)	H
Trounce	fatty acids + pyrethrin	I(7)	I	I	I(7)	I(7)
Vendex	fenbutatinoxide	S	I	S	S	S
Vydate*	oxamyl	H(56)N	H(56)	H(56)	H(56)	H(56)
Zineb	zineb	S	S	S	I	I

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Appendix 2. Plant Nutrient Deficiency Symptoms

Nitrogen	Plant light green with lower leaves yellowing, slow growing.
Phosphorus	Plant dark green, developing a purplish color, slow growing, stunted.
Potassium	Chlorosis developing at leaf tips, moving down the edges of the leaves and between the veins, symptoms developing on lower leaves first.
Magnesium	Interveinal chlorosis beginning on older leaves, chlorotic patches developing to be fairly large, 0.5 - 0.75 mm in diameter. Can also develop a reddish-purple hue at the margins of the chlorotic spots.
Calcium	Deficiencies occur at growing points, young developing leaves at the terminal buds develop a "hooked" appearance at the tips, later leading to browning (tip burn) and die-back. Increased severe blossom end rot (BER) of fruit.
Sulfur	Plants light green over entire plant, symptoms can be confused with nitrogen deficiency. Nitrogen deficiency initially affects the older leaves first.
Iron	Interveinal chlorosis of young leaves, veins remain green giving a finely netted appearance to the leaves. Interveinal chlorosis will eventually spread to the older leaves.
Manganese	Interveinal chlorosis of young leaves. Manganese deficiency is difficult to distinguish from iron deficiency based on visual symptoms.
Copper	Young leaves permanently wilted, unable to stand erect. Eventually, the growing point browns and dies.
Zinc	Interveinal chlorosis of new leaves that produces a "banding" appearance. As the condition progresses, the new internodes shorten producing a rosette appearance at the tops of the plants.
Molybdenum	Deficiency symptoms resemble nitrogen deficiency symptoms, older and middle leaves become chlorotic first. Margins of the leaves can develop a curled appearance, formation of flowers is restricted.
Boron	Abnormal development of growing points, eventually becoming stunted and die.
Chlorine	Chlorosis of younger leaves and wilting of the plant and overall wilting of the plant.

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